Evaluation of Corn Earworm Damage and Incidence of Blank Tip in Corn Grown in Hawaii and Its Significance to Pest Management

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The corn earworm, *Heliothis zea* (Boddie), is a serious pest of corn in the mainland USA as well as in Hawaii. Most sweet corn growers on the mainland rely heavily on insecticide treatments for control of this pest (Linduska and Harrison 1977). In contrast, farmers in Hawaii rarely use insecticide treatments; instead, they cut off the corn earworm-damaged portion of the ear prior to packaging them for market. As a result these growers are able to divert money not spent on earworm control to other production costs such as fertilizers, herbicides, or insecticides for the control of other insect pests.

In addition to damage by the corn earworm, the ear of corn grown in Hawaii often shows a condition referred to as blank tip (Napompeth and Nishida 1974). This condition, not prevalent in the mainland US, is characterized by 1-5 cm of undeveloped kernels at the distal end of the cob. Since a blank tip is also one of the major factors reducing the number of marketable kernels, it is also considered in this paper.

An insect-resistant variety of corn can be grown with a minimum of insecticides which is probably the best way to take advantage of the complex of natural enemies usually common in corn silks in Hawaii (Vargas and Nishida, 1980). For this reason, lines of corn of commercial potential in Hawaii were examined for resistance to the corn earworm and the incidence of blank tip.

MATERIALS AND METHODS

Five lines of commercial corns were grown from August to October 1977 at the University of Hawaii Agricultural Experiment Station, Waimanalo Farm, Waimanalo, Oahu. Three sweet corn lines, "Supersweet", H-68, "Hawaiian Sugar", and 2 dent corn lines, 610 and 788, were included in this study. Three consecutive rows, 50 m long, of each line of corn were planted for a total of 15 rows per replicate. Cultivation was according to local practices without the application of insecticides.

In order to compare the 5 lines for both corn earworm damage and incidence of blank tip, crop life tables were constructed for each line using a procedure similar to that of Napompeth and Nishida (1974). At silking, 10 ears were sampled from the center row of each line and placed in separate bags. This sampling was continued weekly from silking until harvest. The

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sampled ears were each taken to the laboratory and refrigerated until counts were made. Each ear was examined for number of normal kernels, number of blank kernels, and number of earworm damaged kernels. At silking, the immature kernels were nothing more than a small nub to which the silk strand was attached. As the kernels developed, the blank kernels remained small and shrivelled. From these data, the fate of the initial cohort of kernels could be determined from silking to harvest. The format and symbols were the same as those used by Harcourt (1970):

x = Growth period in week
lx = Number of kernels per ear at the begining of period x
dFx = Mortality factor
dx = Number of kernels lost per ear
100rx = Percent loss based on initial population

In addition to the above analysis, each line of sweet corn was rated based on the depth of penetration by the earworm. Penetration was measured by means of a small wooden apparatus designed to hold an ear of corn in place. It was equipped with a centimeter ruler from which the depth of penetration could be read. The husk of each ear was removed before placing it in the measuring apparatus. Data were taken on the number of infested ears, depth of penetration of the earworm into the ear and cob, and the length of cob removed due to blank tip. Since earworm damage and blank tip occur at the distal end of the cob, commercial corn growers cut off this defective portion and refer to the procedure as "tipping". Therefore, tipped ears are ears in which the tips have been cut off due to earworm damage, blank kernels, or both.

For the purpose of exploring the automated removal of tip damage, a detailed study of the marketing potential of the line Superweet was made. For this purpose a random sample of 100 ears of Supersweet was examined.

Results

Earworm Damage

Table 1 compares kernel mortalities of 5 lines of corn for earworm damage in the form of life tables. For the sweet corn lines the percentages of kernels destroyed by the corn earworm were 3.0, 3.4, and 5.3 for Hawaiian Sugar, H-68, and Supersweet respectively; and for the dent corn lines the percentages were 6.8 for 610, and 2.9 for 788. Earworm damage during the early period of ear development was low because the larvae being small, mostly fed in the silk tube. However, kernel mortality due to earworm was high near harvest since 5th and 6th instar larvae were extremely voracious and fed almost exclusively on the kernels.

Table 2 summarizes damage by corn earworms to the 3 lines of sweet corn based on penetration data. The percentage of infested ears ranged from 77 to 90%. Penetration into the cob was 0.9-3.6 cm. The lines rated in order of increased penetration by the earworm were Hawaiian Sugar, Supersweet, and H-68. No significant differences existed among the lengths of the 3 lines after earworm damage and blank tip were removed. Data indicated that the silk tube of Hawaiian Sugar was the longest and

TABLE 1. *Comparison of crop life tables for the corn lines; H.S., Hawaiian Sugar; H-68; Supersweet, S.S.;* 610; *and* 788; *University of Hawaii Agricultural Experiment Station, Waimanalo Farm, Waimanalo, Oahu,* 1977.

Growth Interval x	Number of Kernels 1_x			Mortality Factor dFx	Number of Kernels Lost dx			Percent Loss 100rI		
	H.S.	**H-68**	**S.S.**	Sweet Corn	**H.S.**	**H-68**	**S.S.**	**H.S.**	**H-68**	**S.S.**
1	669	718	684	Pollination Failure	49	84	66	7.3	11.7	9.6
2	620	634	618	Earworm	8	11	12	1.2	1.5	1.8
				Unknown	36	70	73	5.4	9.7	10.7
3	576	553	533	Earworm	12	14	24	1.8	1.9	3.5
				Unknown	8	1	9	1.2	0.1	1.3
4	556	538	500	——						
	610	**788**		Dent Corn	**610**	**788**		**610**	**788**	
1	811	763		Pollination Failure	121	91		14.9	11.9	
2	690	672		Earworm	9	9		1.1	0.6	
				Unknown	44	50		5.4	6.6	
3	637	618		Earworm	21	11		2.5	1.4	
				Unknown	—	18		—	2.4	
4	616	589		Earworm	25	7		3.1	0.9	
				Unknown	—	2		—	0.3	
5	591	580		——						

TABLE 2. *Comparison of* 3 *lines of sweet corn with respect to penetration by the corn earworm and marketable ear, University of Hawaii Agricultural Experiment Station, Waimanalo Farm, Waimanalo, Oahu,* 1977.

Corn Line	% Infested Ears	Length of Coba (cm) ($\bar{x}$ ± SD)	Length of Silk Tube (cm) ($\bar{x}$ ± SD)	Penetration into Cob by Earworm ($\bar{x}$ ± SD)	Length of Tipped Ear (cm) ($\bar{x}$ ±SD)
H.S.	86	19.2 ± 1.1 a	5.7 ± 1.7 a	0.9 ± 0.7 a	17.7 ± 2.2 a
H-68	90	20.4 ± 1.7 a	3.0 ± 1.7 b	3.6 ± 2.1 b	17.0 ± 1.5 a
S.S.	77	20.8 ± 1.8 a	3.3 ± 1.7 b	3.3 ± 1.0 b	16.8 ± 2.2 a

[a]Means in the same column followed by the same letter are not significantly different, P = 0.05, Duncan's multiple range test.

that it had the least amount of penetration. However, previous comparisons with a susceptible line possessing a silk tube of similar length indicated that additional factors were involved. Such a factor found in the line Hawaiian Sugar was husk tightness. No other line tested possessed a husk of comparable tightness. The dent lines were comparable to the line Hawaiian Sugar in husk tightness, but possessed shorter silk tubes.

Pollination Failure

The percentage mortalities of kernels caused by pollination failure were 7.3, 9.6, 11.7, 11.9, and 14.9 for Hawaiian Sugar, Supersweet, H-68, 788 and 610, respectively (Table 1). Evidence of pollination failure was noted during the 1st wk of silking. Figure 1 shows the proportion of kernels surviving for each line tested.

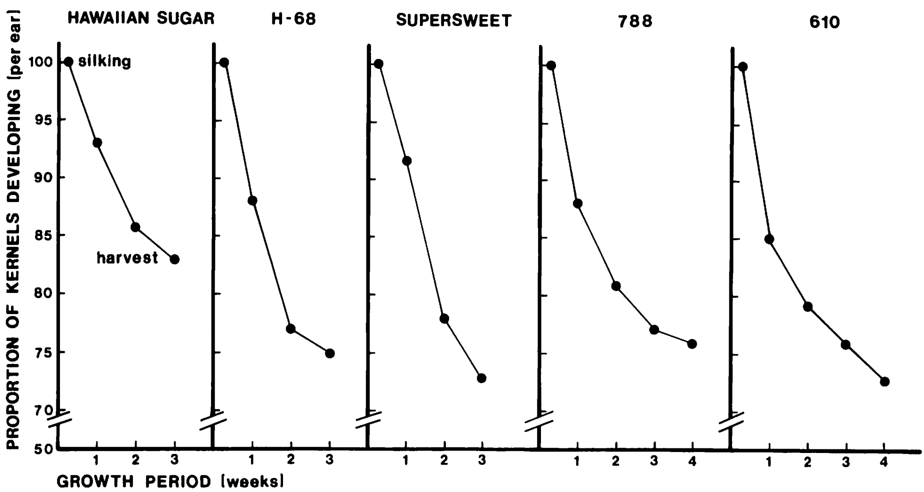

FIGURE 1. Comparison of the proportion of kernels surviving for 5 lines of corn, University of Hawaii Agricultural Experiment Station, Waimanalo Farm, Waimanalo, Oahu, 1977.

Relationship between Earworm Penetration and Blank Tip

Although there appeared to be a tendency for blank tip to impede earworm penetration in some individual cases, correlation analysis showed that the effects were not significant with $r = 0.11$.

Prediction of Tip Removal

Data on tip removal were used to predict the amount of the ear that must be cut off without husk removal. This might be a first step in the development of an automated procedure. A frequency distribution on the length of the tip removed to make ears marketable, constucted from a random sample (N = 100) of a planting of Supersweet, showed a near normal distribution. These data were graphed on probability paper. Two lines were calculated: one, to show the relationship between the amount of tip removed (cm) and the percentage of ears in the sample free from earworm damage and the percentage of ears in the sample from both earworm damage and blankness. A 100% level of earworm-free ears required 6.0 cm; and 75% required 3.9 cm. For marketable ears free from both earworm and blank tip, greater amounts had to be removed from the cob.

Discussion

In an attempt to rate the lines of corn for damage by the corn earworm, 2 methods are used: life table analysis and measurement of penetration into the tip of the ear. Each method had its advantages. Life table analysis presented weekly analyses of damage, more precise estimates of total kernel damage, and added information on the occurrence of underdeveloped kernels; while the measurement of penetration was fast and had direct application to the "tipping" of sweet corn. In rating the sweet corn lines both methods showed the same result: Hawaiian Sugar was least damaged by the earworm. Although the lines varied in ear size, each produced about the same size marketable ear, i.e., after removal of earworm damage and blank tip.

No attempt was made to indentify the factors for resistance. However, it is generally felt that sweet corn varieties are favored by earworms over field varieties (Barber 1937). Previous studies showed that the line 610 possessed a relatively short silk tube, this may have contributed partially to its susceptibility to earworm. It has been suggested in the literature that ears protected by a long, tight husk have less earworm damage (Collins and Kempton 1917, Phillips and Barber 1931). Such was the case with the line Hawaiian Sugar which showed the highest resistance to earworm attack. Evidence indicated that length and tightness of the husk were especially important in imparting resistance to the earworm in this line. Additional factors suggested by other investigators include nutritional differences in the silks and kernels (Collins and Kempton 1917), and the presence of a "lethal" factor in the silks (Walter 1957, Wiseman et al. 1978).

In every line examined pollination failure was responsible for higher kernel mortality than earworm damage. This was in close agreement with the findings of Napompeth and Nishida (1974) who first pointed out that kernel loss due to lack of pollination is greater than that caused by the earworm. However, no clear-cut relationship emerged between corn earworm damage and blankness. Since blankness and the corn earworm affect primarily the tip of the ear, tipping is practiced whether an ear is infested or not. It would be beneficial to the grower to select lines not only rated for earworm resistance but also for absence of blank tip, the cause of which is not known.

Tipping is an added cost of production, but it is a practical procedure in the marketing of sweet corn in Hawaii. Automated removal of damage might in the long run be more cost-effective. Could the probability data of this study be used as a guide to the amount of tip to be removed? The answer to this question turned out to be "no" for 2 principal reasons. First, the magnitude of variation of earworm damage is too great to make standardized machine tipping economically feasible. For a 95% level of earworm-free ears, 6 cm of tip would have to be removed from the ear. Based on a mean penetration into the ear by the earworm of 3.3 cm, this would result in an average loss of 2.7 cm of good kernels, which would not be economically acceptable. Second, the occurrence of blank tip in addition to earworm damage often demands an additional amount of tip removal. For these reasons the most practical and efficient way of dealing with earworm damage and blank tip is to remove the damaged portion mechanically after husk removal.

It is very rare that 95% damage-free ears are attained with insecticides. When these levels have been attained, they have required from 4-16 applications of an insecticide per crop (Anderson and Nakakihara 1968). This is indeed a heavy use of pesticide.

Until other effective control methods are developed the practice of tipping sweet corn forms the basis for the management of the corn earworm in sweet corn in Hawaii. The corn earworm infesting sweet corn is normally considered a severe pest with an economic threshold approaching zero. This would preclude the use of predators and parasites in a pest management capacity. Van den Bosch and Stern (1962) cite the corn earworm as an example of a pest heavily attacked by predators and parasites, but with severe injury still occurring to sweet corn. However, in Hawaii where the marketing practice of tipping is employed the situation is changed drastically. The economic threshold is no longer zero and the predators and parasites assume an important position in the management of the corn earworm.

Summary

Lines of corn commonly grown in Hawaii were analyzed for damage by the corn earworm and blank tip. Two methods of analysis were used: life table analysis and depth of penetration into the tip of the ear. The sweet corn lines rated in order of increased damage by the earworm were Hawaiian Sugar, H-68, and Supersweet. The lines rated in order of highest percentages of blank kernels were Hawaiian Sugar, Supersweet, H-68, 788, and 610. Evidence suggested that not only length of the silk tube but also tightness of husks were important factors in determining earworm resistance. In addition, the marketing practice of tipping was examined. Pest-management stategies based on the varietal characteristics of corn and the marketing practice of tipping are important in the effective management of the corn earworm in sweet corn in Hawaii.

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